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A Geotechnical Study for Land-use Planning Purposes

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SYNOPSIS The purpose of this paper is to describe the different stages and the final results of a geotechnical study for use by planners in zoning a seismic area in the south of Italy. Particular attention is given the method followed to draw a "Geotechnical Seismic Zoning Map". Also described in summary fashion are a number of dynamic laboratory tests carried out and their results.

INTRODUCTION

In many countries the role of geotechnics in territorial planning and organizing is becoming more and more important. It is not by chance that during the "Tenth International Conference on Soil Mechanics and Foundation Engineering" a complete session was dedicated to "Environmental Geotechnics". It is by now a common opinion that the contribution of geotechnics is much more useful in suggesting indications when planning than in finding solutions (often difficult and expensive) to problems which may occur after the decision-making process. Very useful for this purpose are geotechnical maps whose methodological development has, in recent years, received important and interesting contributions (Sembenelli, 1982).

Described in this paper are the different stages and the final results of a geotechnical study carried out in a future development area of Potenza, a regional chief city in southern Italy. Particular stress is given to the method followed for the compilation of a Geotechnical Seismic Zoning Map.

The study has been ordered by the City Council of Potenza to provide planners with a complete information system on the physical characteristics of the area in question.

INFORMATION ON THE AREA UNDER STUDY

Potenza, at the present time, is classified by Italian law as a "seismic area". It is opportune to recall that this city has been greatly damaged by the earthquake of 23rd November 1980.

The approximately one square kilometer area being studied is located on a slope in suburban Potenza (Fig. 1).

The morphology is characterized by slopes averaging 10% (maximum values reach 35%).

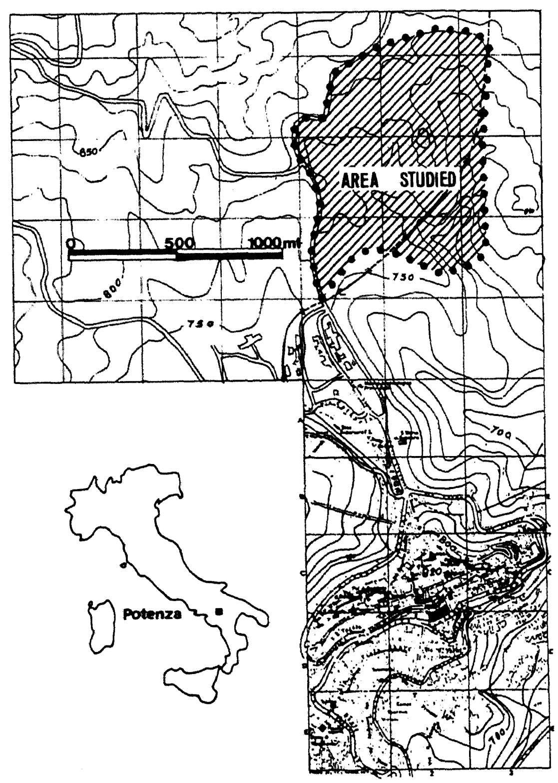

Fig. 1. Geographic Position

As regards the geology, the soils are mostly of sedimentary origin, detrital in nature: clays, silt-clays, sands and conglomerates. Such soils are overlain with more less recent cover consisting of alluvials, colluvia and detrital deposits.

METHODOLOGY

We have used the following methodology.

(i) First of all we have selected the potential building sites within the area under study by rejecting the unsuitable lots of land on the grounds of the following parameters:
- vegetation. A wooded area on which no building is permitted was rejected at the outset.
- ground slope line. Areas having slopes in excess of 30% were rejected both due to high construction costs and due to environmental damage that eventual relevant earth movments would cause.

(ii) A detailed investigation has been carried out on the selected sites:
- analysis of aerial photographs
- boring tests with sample taking
- laboratory tests (shear and triaxial tests, consolidation tests, dynamic tests)
- field piezometric measurements
- up-hole wave propagation tests
- standard penetration tests

(iii) All data collected have been studied. Particular attention has been given to the interesting results of dynamic laboratory tests on the 'blue clay', a stiff soil typical of Potenza. In fact, for the first time a cyclic triaxial compression test has been carried out on this cohesive soil.

(iv) To summarize the results of the above-mentioned analyses graphically we have drawn the seven following documentation maps to 1:1000 scale:
- soil use map
- geomorphological map
- geolithological map
- two hydrological maps
- three-dimensional soil profile map
- slope stability map

(v) To give exact indications to planners, we have produced the final document of the study: a geotechnical seismic zoning map.

DYNAMIC LABORATORY TESTS

Inasmuch as space is limited and we are unable to give due attention to all investigations made, we deem it opportune to limit ourselves to illustrating, at least with regard to basic essentials, a number of dynamic laboratory tests carried out on representative soil samples of the area under study: the so-called 'blue clay'. This is a stiff cohesive blue-grey soil typical of the city of Potenza. The tests described have all been carried out by the ISMES Geotechnical Laboratory of Bergamo (Italy).

We have carried out two cyclic triaxial tests on undisturbed samples 38.1 mm in diameter and 76.2 mm in height taken at 10.00 to 10.50 meters: one being the so-called strength test to determine deformation under cyclic loads, the other being the so-called property test to determine dynamic shear modulus G and damping ratio. The soil samples have been consolidated to an isotropic stress of 500 kPa prior to testing.

Strength Test

The sample has been subjected to a vertical cyclic load equal to 326 kg/square cm. The test was continued until 500 cycles had been completed. Test results are plotted in Fig. 2.

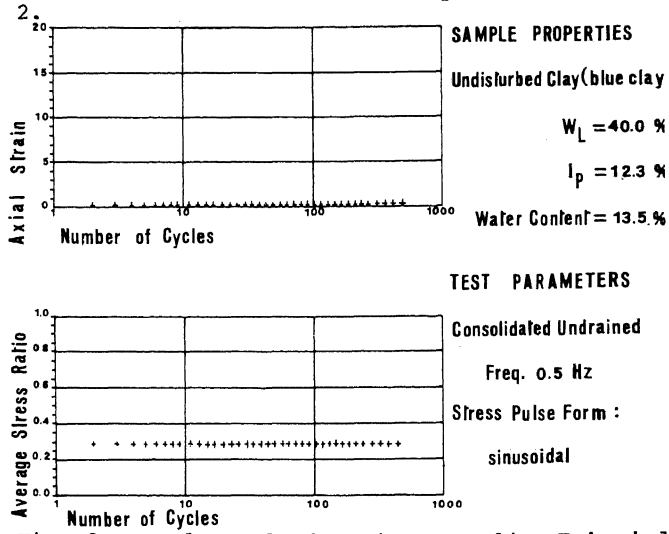

Fig. 2. Results of the First Cyclic Triaxial Test: the Strength Test

It can be seen from this figure that the soil sample was not affected by the application of a "stress ratio"" equal to 0.3. The axial deformations are insignificant. No reduction in soil strength was noted.

Property Test

The sample has been subjected to 25 load cycles. After recording residual values of pore pressure, deformation and load at the end of the cycles, the specimen has been consolidated again and then a new series of load cycles producing greater deformations has been applied. The test was considered to have been completed when a deformation of 0.5% was reached. The results of the tests plotted in Fig. 3 show a damping ratio equal on the average to 10% and a value of shear modulus G ranging, in relation to increasing loads, from 200 to 55 kg/square cm.
It may be of interest to note that the relationship between shear strain and damping ratio is in substantial agreement (Fig. 4) with that obtained by Seed and Idriss (1970).

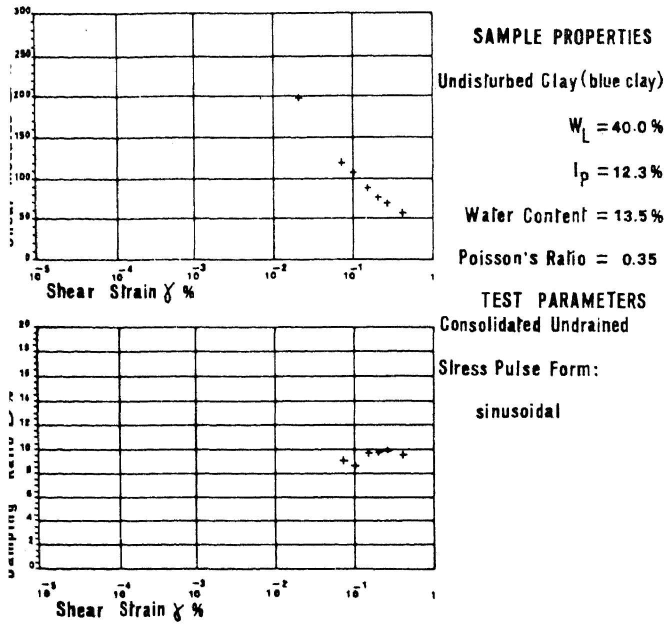

Fig. 3. Results of the Second Cyclic Triaxial Test: the Property Test

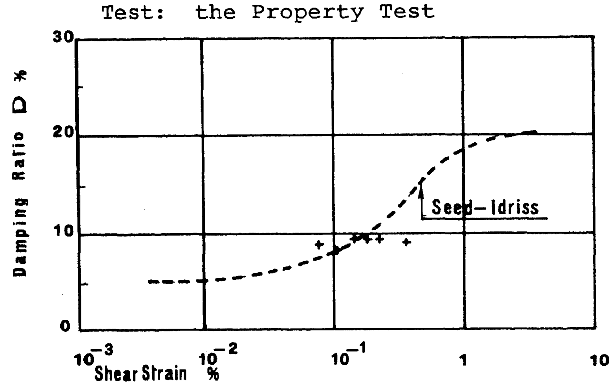

Fig. 4. Damping Ratio versus Shear Strain: Comparison between the Data of This Study and the Curve Obtained by Seed and Idriss.

DOCUMENTATION MAPS

Documentation maps together with the Geotechnical Seismic Zoning Map constitute the so-called Geotechnical Atlas which comprises the different aspects of a territory's features. It is useful to point out that a 'documentation map' is a report containing facts: the parameters considered there are merely represented and not interpreted. Described briefly herein are the contents of every map drawn.

Soil Use Map

The areas are differentiated in relation to the present land use and their potential. This map has been of considerable help to planners because from it they were able to verify the mutual influences and hence the compatibility of their technical decisions with environmental conditions.

Geomorphological Map

This map summarizes the results of the geomorphological investigation carried out by means of on-site technical inspections and by the study of aerial photographs.

Geolithological Map

This map shows the geolithological conditions of the area under study. A summary description of the main formations has already been made under 'Information on the Area under Study' of this paper. It is nevertheless important to stress that 'blue clay' predominates over the other soils present.

Hydrological Maps

Shown in these two maps are the characteristics of the surface and underground hydrography. The lowest depth of waterbearing stratum is also drawn.

Three-dimensional Soil Profile Map

We have drawn the underground soil conditions resulting from the exploratory borings, standard penetration tests and up-hole wave propagation tests on a three-dimensional system. It is a very useful map as it provides an immediate image of all the underlying soils.

Slope Stability Map

The areas of equal stability factor have been mapped. It is important to emphasize that the "pseudo-static" method of analysis has been used in the calculations. It may be of interest to note that the lowest safety factor obtained was 1.7.

GEOTECHNICAL SEISMIC ZONING MAP

This map is the final and most important result of the whole research project. To produce it we have used the following procedure.

(i) We have chosen the three following parameters, considered the most representative for the object of our study:
- slope stability
- local seismic amplification factor
- standard penetration resistance

It is important to emphasize that the local seismic amplification factor has been calculated according to Medvedev's equation. As regards the standard penetration resistances, it is useful to specify that we have calculated (for each penetration point) the weighted mean of the resulting values.

(ii) The values of each parameter have been classified into two groups, as shown in the following schedule:

	Slope Stability
A	Safety Factor ≥ 2
B	$1.5 \leq$ Safety Factor < 2
	Standard Penetration Resistance
1	Number of Blows ≥ 10
2	Number of Blows < 10
	Seismic Amplification
α	Factor < 1.2
β	Factor ≥ 1.2

It is worth our while to point out that the above numeric values concern this specific case. They may vary therefore if the method is applied to other territorial situations.

(iii) All data have been combined to identify soil classes by triple class indexes: each index contains an indication of slope stability, seismic amplification factor and prenetration resistance. The areas of equal index have been mapped (Fig. 5).
The map has also been made to show a number of areas without any indexes, identified only by the letter 'R'. These are areas for which no form of construction is recommended due to both morphological and geotechnical problems.

(iv) We have been able, on the grounds of the zoning map drawn in this way (to 1:1000 scale), to provide planners with indications illustrating the characteristics and recommendations for each area, as follows:

Zone $A_{2\alpha}$

Characteristics

- A areas in which the safety factor, as regards slope stability, is ≥ 2;
- 2 soils with an elevated coefficient of compressibility;
- α the local seismic amplification is negligible.

Recommendations

In this area intensive urbanization is possible but only on condition that the differential settlements will be studied in detail. Deep foundations should be compulsory for large buildings.

CONCLUSIONS

The geotechnical study just illustrated ha furnished, as was our intention, a number c indications that have since turned out to k extremely useful to planners in that the served as valid basic documentation for coi rectly zoning the area.

The method followed for the compilation c the Geotechnical Seismic Zoning Map, in parti cular, has made it possible to obtain a suffi ciently complete document which is at the san time easy to interpret. A document on the basi of which we have sought to provide clear ar swers at the quantitative level and not onl at the qualitative level without nonetheles ascribing to the numeric values greater impoi tance than their real significance.

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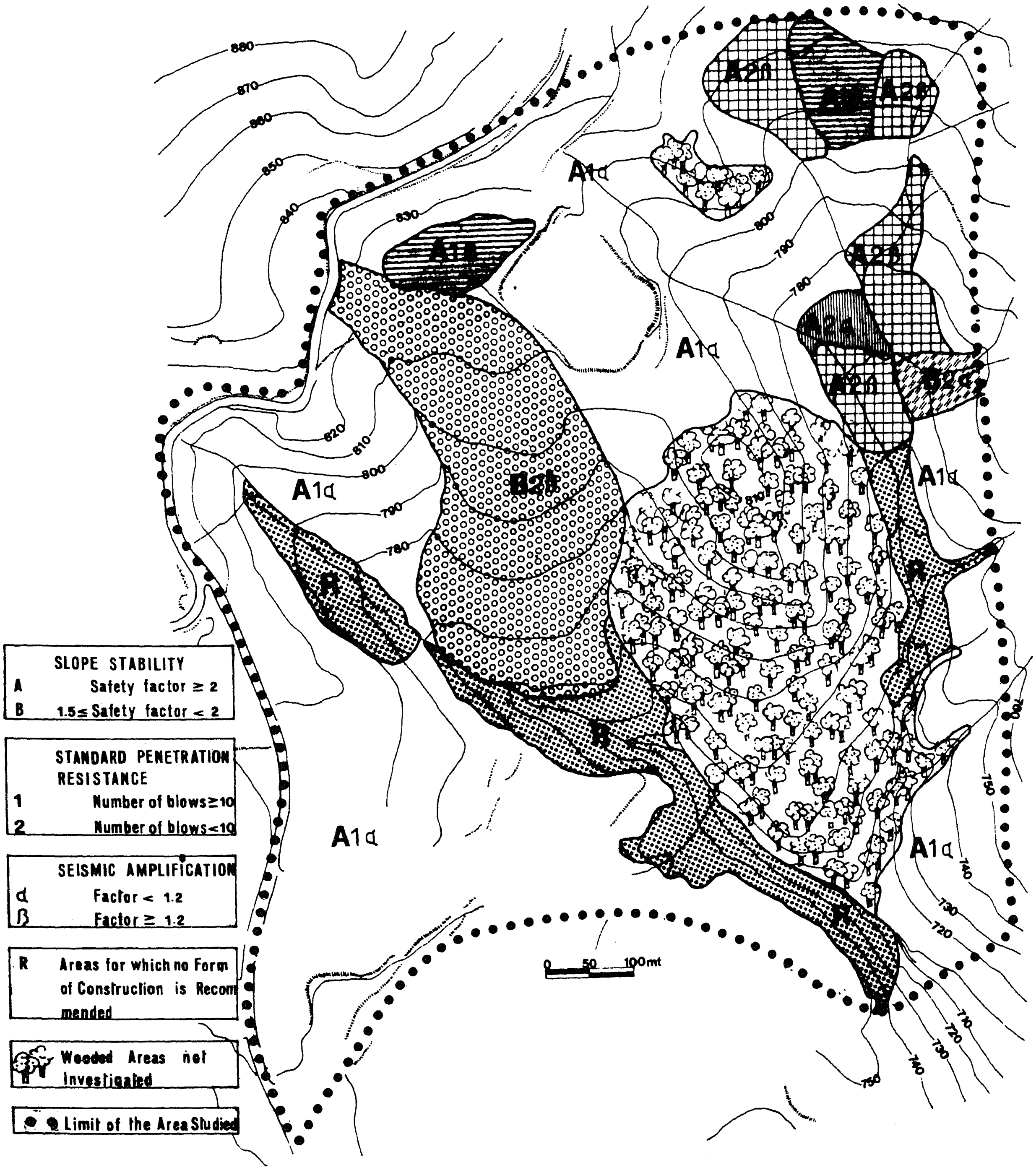

Fig. 5. A Reproduction of the Geotechnical Seismic Zoning Map